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GEOCHEMICAL LABORATORY

Technical Report No. 5

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Age Measurements in Marine Cores by Carbon 14 I.

Lamont Geological Observatory

(Columbia University)

Palisades, New York

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Technical Report No. 5

by

J. Laurence Kulp

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Abstract

The age of a considerable number of deep ocean core samples have been determined by their Carbon 14 content. The method gives promise of great usefulness in determining rates of sedimentation of various sediment types, in correlating worldwide meteorological and geological events of the late Pleistocene, and in understanding certain ocean bottom processes such as turbidity current action. Normal sedimentation for typical green gray foraminiferal clay appears to be on the order of 10-20 cm. per 1000 years whereas some of the fine globigerina ooze is closer to 1 cm. per 1000 years. The carbon in the core carbonate apparently does not exchange with modern carbonate in the water to an appreciable extent. The rate of carbonate deposition in atoll lagoons may exceed 35 cm/100 years.

Age Measurements in Marine Cores

by Carbon 14 I.

J. Laurence Kulp

Introduction

The age relationships of the layers of deep sea sediments are of first order importance in the understanding of the geology of the ocean floor. Not only can rates of sedimentation be determined, but worldwide meteorological changes, concentrations of volcanic activity and various submarine processes may be inferred.

The first attempt at quantitative age determination of the sediments was made by Piggot and Urry (1941) by the Ionium Method. Re-evaluation of their data plus some new radon data obtained in this laboratory suggest that this method is severely limited by the nature of the sediment and the continuity of the sedimentation process. The widespread frequent occurrence of turbidity current deposition makes it seem rather certain that in most deep sea cores a simple radon vs. depth curve will not yield reliable age data. If a sufficiently homogeneous core or part of a core representing continuous deposition is available, the ionium method may be applicable.

Since the calcium carbonate content in most deep sea cores is appreciable (5 - 100%), it is possible to study the age of a given depth of sediment by the Carbon 14 method (Libby, W.F., Anderson, E.C., and Arnold, J.R., 1949).

This is an absolute method which does not depend on continuity of deposition for its validity.

Sediments from various depths in some representative deep sea cores (North Atlantic) and one shallow Lagoon core (Bikini) have been subjected to Carbon 14 measurement. The results are sufficiently encouraging to warrant widespread application of the method to many cores.

Experimental Procedure

The core specimen is selected over a sufficient length to provide an adequate sample of carbon, i.e. 8 grams. The core specimen is then treated with con. c.p. HCl to liberate the CO_2 which is dried and condensed in a trap surrounded by liquid air. After evacuating to remove impurities, the solid CO_2 is allowed to expand into a solution of ammonia from which the carbon is precipitated as $CaCO_3$. This is thoroughly washed. The $CaCO_3$ is then acidified, the purified CO_2 released and then reduced over hot magnesium metal. The resultant carbon, magnesium oxide, and excess magnesium are broken out of the tube and subjected to a series of leaching steps which yield a carbon containing less than 1% ash. This carbon is then mounted in a screen wall Geiger tube which is placed inside an elaborate shield consisting of 12 tons of iron, a ring of anticoincidence counters, and an inch of mercury. This arrangement permits the precise measurement of the natural radiocarbon content up to an age of 30,000 years ago. The detailed procedure is being published elsewhere (Kulp, Tryon and Feely, 1952).

Results

The results of this investigation are summarized in Tables 1 and 2 and Figure 1. The reproducability of the method is indicated by the repeat measurements shown in Table 1. The plus or minus is the statistical probable error from the counting results and does not include other possible systematic errors. However, considerable data has now been accumulated in this Carbon 14 laboratory which strongly suggests that the statistical counting error is the dominant one.

A. Exchange problem

A major problem which arises in the use of the calcium carbonate in marine sediments is the possibility of exchange of the carbonate carbon in the sediments with the carbonate carbon in the adjacent water.

There are at least three lines of argument against appreciable exchange which are now available. The data for each argument is presented in Table I. Case 1 is taken from Libby's data (1951) on a wood and shell sample from one archeological site and an animal tissue and shell sample from another site. It is observed that the ages agree within the statistical error. A rather large number of similar sets of contemporaneous wood and shell from various localities are undergoing preparation for counting in this laboratory. Case 2 is taken from early or pre-Wisconsin eolianites (loosely consolidated windblown limestone) which occur near the surface on the island of Bermuda.

It is seen that these older but fully exposed eolianites are not contaminated with modern carbon. The eolianite corresponding to the Mankato stage, however, gives an age of about 17,000 years in agreement with the expected time span for the late Wisconsin. Certainly if exchange were to occur, it would be most likely under these conditions where ground water percolates through loosely consolidated limestone. The negative result is most encouraging.

The third case duplicates the conditions of the exchange problem in the deep sea cores. Two samples were measured from a core taken in 1150 meter water on the East slope of Bermuda where the stratigraphy consists of 25 cm. of recent rapidly deposited fine lime mud deposited directly on Pliocene lime sediment. As is shown in Table 1, the recent mud measures approximately the expected value while the Pliocene sample taken only a few centimeters below the unconformity shows no appreciable carbon 14.

While it is still possible that carbon isotope exchange may appreciably affect the C14 age determination under certain special conditions, it appears from the above results that under most conditions, it can be safely assumed that the exchange effect is negligible. Further studies of this important problem are being carried on.

B. Bikini Lagoon Core

Table 2 shows the results of the Carbon 14 age measurements on three samples of a core taken in Bikini Lagoon prior to the first atomic explosion tests. The rate of sedimentation is clearly greater than 15" per 100 years. This is obviously very fast compared with normal open ocean sedimentation. According to certain of the more probable theories of atoll formation, (Kuenen 1950), the growing atoll had to keep up with the rising sea level since the conclusion of the Wisconsin glacial advance. The actual rise in sea level is somewhat difficult to obtain precisely but is probably on the order of 200-400 feet. If the date that the last rise began is taken as 11,000 years ago as determined by Carbon 14 measurements in several places, a rate of growth of 3-4 cm/100 years is required. That the rate of sedimentation inside the lagoon is much greater than this suggests that the lagoon should be filling up.

C. Deep Sea Cores

Reconnaissance measurements of the natural radiocarbon content of several representative deep ocean cores have been made. The results are summarized in Table 2.

A-152-118 which is located on the North West flank of the Mid-Atlantic Ridge near latitude 35° consists of pink foraminiferal clay from 0-92 cm. and 350-500 cm. Between 92-350 however is a gray clay foreign to the rest of the core. The age measurements suggest that a turbidity current deposited 250 cm. of older material suddenly, interrupting the normal deposition of the pink clay (see Figure 1). The age measurements suggest that the normal sedimentation rate for the homogeneous pink clay is on the order of 1-2 cm/100 years. This is faster than is generally assumed for deep sea sedimentation. Since there is no lithologic evidence for a slower rate of sedimentation in the upper 5 cm. it must be assumed either that sedimentation ceased about 5000 years ago or that some of the later sediment has been eroded off.

Core A-164-38 is an ideal case of turbidity current deposition, (Ericson, Ewing, and Heezen, 1951). Although the water depth is 4400 m. this core shows perfectly graded bedding from very coarse shallow water shells at the bottom to extremely fine lime mud at the surface. This core was taken South east of Bermuda. The material was probably derived from the early Pleistocene shallow water sediments high on the submarine slope. The C14 age of the bottom shell fragments and the sample of intermediate texture at 88-92 cm. prove the antiquity of the coarse material. The apparent age of the fine material in the upper 12 cm. is probably to be ascribed to the fact that the turbidity current picked up a small percentage of recent fine lime mud, so common in the area, so that as the sediment settled out the contaminating modern material went into the top fine fraction.

Core C-10-5 from the Muir Sea Mount, has a different lithology and history from either of the above cores. The top few centimeters consist of fine globigerina ooze suggestive of slow recent deposition. The average rate of deposition for the top 10 cm. appears to be about 1 cm/1000 years. Below this is a tan foraminiferal clay which is probably to be attributed to turbidity current deposition. At 90 cm. the sediment becomes a gray foraminiferal clay with colder water forms. This continues to about 350 cm. and may represent normal deposition. The date of 19,600 ± 900 for the layer 149-168 cm. suggests a rate of deposition 5-10 cm/1000 years.

Core C-10-14 consists of globigerina ooze suggestive of slow deposition in the upper 85 cm. From 85-110 is a green mud under which is a homogeneous rose gray clay. The age at 19-29 cm. suggests slow deposition for the globigerina ooze.

Conclusions

1. The measurement of the concentration of natural radiocarbon in the carbonate phase of deep sea sediments can be used to determine the age of a particular layer.
2. In some cases the Carbon 14 measurement can be used to detect certain phenomena such as reworking of sediments and turbidity current deposition.
3. The carbon in the deposited carbonate apparently does not exchange appreciably with modern carbonate.
4. The rate of sedimentation in atolls may exceed 35 cm/year.
5. Typical deep sea foraminiferal clay has a sedimentation rate of 10-20 cm/1000 years while some of the globigerina ooze appears to have a rate closer to 1-2 cm/1000 years.

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Table 1

Study of Possible Carbon Isotope Exchange

Case 1: Comparison of shell and organic ages from same strata (Data from Arnold and Libby, 1951)

Sample No.	Description	Age
251	Annis mound deer antler 6.5' level	4900 ± 250
116	Annis mound shell 6.5' level	5150 ± 300
136	Charcoal from Hopewell Indian site	1951 ± 200
137	Same as 136 except shell	2285 ± 210

Case 2: Bermuda eolianite samples

Eolianite	North America Stratigraphic Equivalent	Depth below present surface where sampled	Expected Age	C14 Age
Southampton	Mankato	15'	12000-18000	17,000
Somerset	Tazewell or older	6'	older than 25,000	older than 25,000
Signal Hill	Iowan or older	20'	older than 35,000	older than 25,000
Pembroke	Illinoian	8'	older than 100,000	older than 25,000

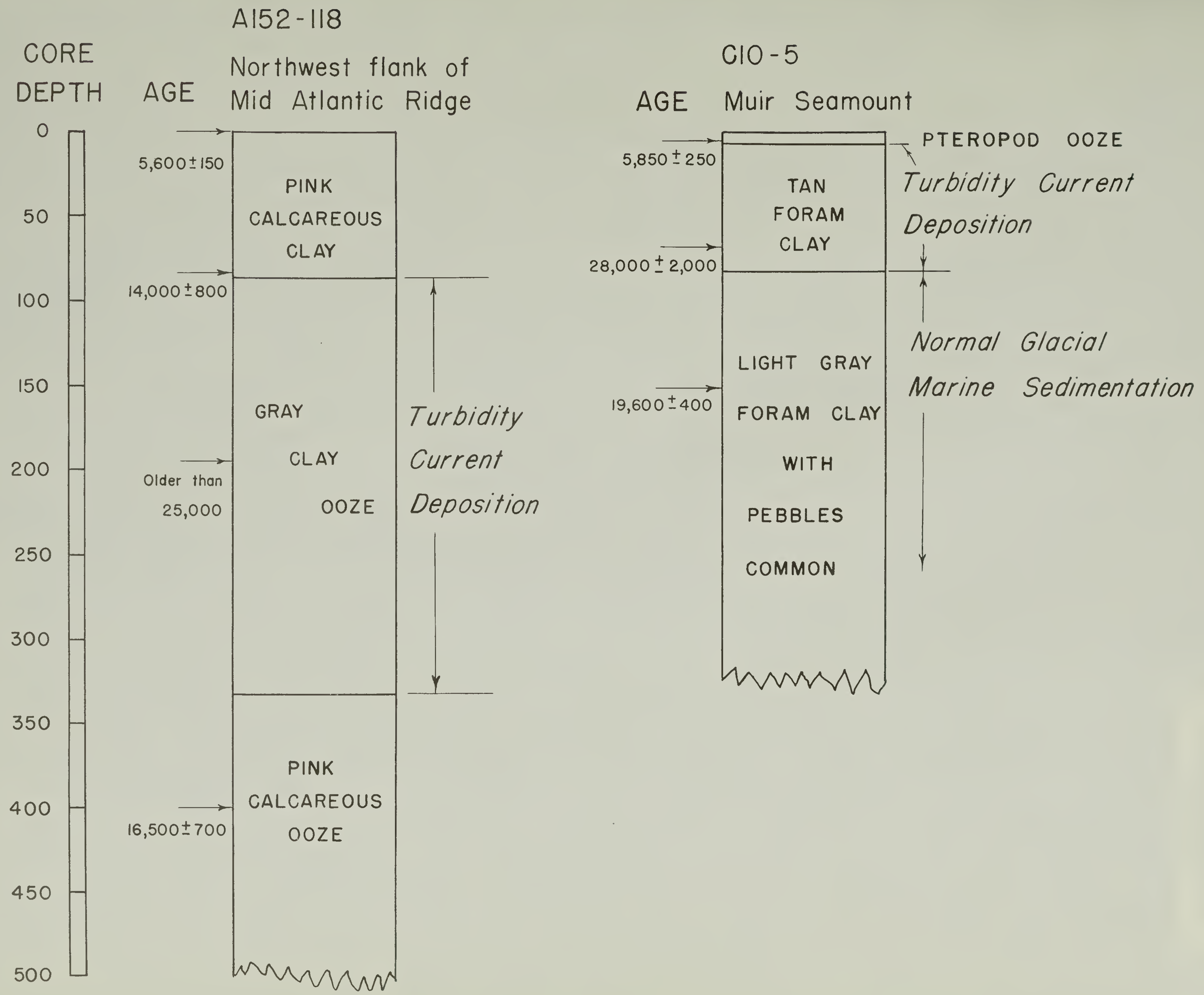
Case 3: Deep Sea Core C-10-7
Latitude 32° 20.9'N., longitude 64° 34.5'W, water depth 1150 m.

Stratigraphy	Sample	Age
0-25 cm. Recent gray coccolith ooze	0-8 cm. (effective age at 4 cm)	Recent
25-287 cm. Pliocene chalk	45-51 cm.	Older than 20,000 years

Table 2

Age Measurements on Some Marine Cores

Core No.	Location	Water Depth	Core Depth	Apparent Age (years)
Bik 224	Bikini Lagoon	42 m.	2-6"	less than 100
	11°35.6'N;		6-10"	less than 100
	165°30.1'E		10-15"	less than 100
A152-118	NW Flank Mid-	4340 m.	0-5 cm.	5,600 ± 150
	Atlantic Ridge		84-92 cm.	14,100 ± 800
	35°07'N;44°40'W		196-204 cm.	older than 25,000
			396-404	16,700 ± 900
				16,400 ± 800
				Av. 16,500 ± 700
A164-38	S.E. of Bermuda	4400 m.	0-12 cm.	17,000 ± 900
	32°00N; 64°16'W			16,000 ± 1300
				16,600 ± 700
				Av. 16,600 ± 500
			88-92 cm.	older than 25,000
			Cutting edge coarse shell fragments	older than 25,000
C-10-5	Muir Seamount	2670 m.	0-10 cm.	5,850 ± 250
	33°37.4'N;		70-80 cm.	28,000 ± 2000
	62°29.6'W			19,000 ± 2200
				21,100 ± 1800
			149-168 cm.	Av. 19,600 ± 900
C-10-14	Hudson Canyon	2980 m.	19-29 cm.	14,400 ± 700
	38°24'N;			14,100 ± 600
	70°52'W			Av. 14,200 ± 500
			126-143 cm.	older than 20,000


CORE
DEPTH
AGE
A152-118
Northwest flank of
Mid Atlantic Ridge
0
50
100
150
200
250
300
350
400
450
500
5,600±150
14,000±800
Older than
25,000
16,500±700
PINK
CALCAREOUS
CLAY
GRAY
CLAY
OOZE
PINK
CALCAREOUS
OOZE
Turbidity
Current
Deposition
AGE
CIO-5
Muir Seamount
5,850±250
28,000±2,000
19,600±400
PTEROPOD OOZE
TAN
FORAM
CLAY
LIGHT GRAY
FORAM CLAY
WITH
PEBBLES
COMMON
Turbidity Current
Deposition
Normal Glacial
Marine Sedimentation

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